ANALYSIS OF 494 ACCIDENTS, OPEN-PIT IRON-ORE MINES, BENEFICIATION PLANTS, AND SHOPS LAKE SUPERIOR DISTRICT

BY R. O. PYNNONEN, L. J. ZAVERL, AND A. D. LOOK

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ANALYSIS OF 494 ACCIDENTS, OPEN-PIT IRON-ORE MINES, BENEFICIATION PLANTS, AND SHOPS, LAKE SUPERIOR DISTRICT[1/]

by

R. O. Pynnonen,[2/] L. J. Zaverl,[3/] and A. D. Look[4/]

SUMMARY

This publication presents a study by the Federal Bureau of Mines of 494 accidents in open-pit iron-ore mines, beneficiation plants, and shops of the Lake Superior district from March 1949 to June 1956. These accidents caused 499 lost-time injuries, including 12 fatalities. A similar Bureau publication, Information Circular 7744, Analysis of 346 Accidents, Underground Iron-Ore Mines, Lake Superior District, was published in April 1956.

Accident reports were analyzed by the Bureau to show the causes of injuries and the unsafe practices or conditions that caused the accidents. Also shown are the time charges, times of occurrence, ages of the injured by job classification, and experience of the injured in mines and on the job being performed when hurt.

Detailed information is presented on approximately 27 percent of the total number of disabling accidents that occurred in open-pit iron-ore mines, beneficiation plants, and shops in the district during the period covered. The text also contains tabulations of the accident experience and graphs with straight-line injury-frequency, injury-severity, and fatality trends for the period 1946-57.

INTRODUCTION

Information on the 494 accidents presented in this circular was obtained from accident description reports submitted by eight mining companies that are members of the Lake Superior Mines Safety Council and exchange accident reports. These companies operated open-pit iron-ore mines, beneficiation plants, and general shops on the Mesabi and Cuyuna iron ranges in Minnesota and the Marquette, Menominee, and Gogebic iron ranges in Michigan. Accident reports were exchanged to circulate details of the more serious or unusual accidents experienced by the participating companies. These reports followed a standard

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outline, and copies were sent to the secretary of the Lake Superior Mines Safety Council for distribution to participating members.

The number of accident reports exchanged has increased each year since the program was begun in 1944. During 1956, 27.1 percent of the accidents resulting in disabling injuries in open pits, beneficiation plants, and general shops were included in the accident-report exchange.

ACKNOWLEDGMENTS

The cooperation of the executive committee and members of the Lake Superior Mines Safety Council in preparing this circular is appreciated. Acknowledgment also is made to the following mining companies whose accident reports are included in this analysis:

The Cleveland-Cliffs Iron Co.
The M. A. Hanna Co.
Inland Steel Co.
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Pickands Mather & Co.
Republic Steel Corp.
Snyder Mining Co.

GENERAL INFORMATION

The Lake Superior district, long the principal source of iron ore in the United States, has become more dependent on the beneficiation of low-grade ores to meet the demands of the steel industry. About 80 percent of the annual production from the district comes from open-pit mines; except for a few operations in Michigan, most of the open-pit mines are in Minnesota. The Mesabi range open-pit production alone accounted for 63.3 million[5/] of the slightly more than 81 million tons shipped from all district mines during 1957.[6/] Approximately 45 percent of the Mesabi range shipments was beneficiated ore.

Gradual depletion of high-grade ore reserves has necessitated the mining of lower grade ores. The use of lower grade ores, and the demand for higher grade, more uniform furnace feeds by blast-furnace operators has required the installation of beneficiation plants at these operations. Many of these are simple crushing and washing plants that improve the grade by removing silica. Some ores require more complicated methods, such as drying, jigging, heavy medium, or magnetic separation. In all, 77 beneficiation plants were operated on the Minnesota ranges in 1957 compared with 46 in 1946. The man-hours of exposure in these plants has increased more than sevenfold during that period.

5/ Wade, H. H., and Alm, M. R., Mining Directory Issue: Bull., Univ. of Minnesota, 1958, p. 258.

6/ Skillings Mining Review, Lake Superior Iron Ore Shipments From Upper Lake Ports - 1957: Vol. 46, No. 37, Dec. 14, 1957, p. 2.

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Many companies maintain centrally located general shops to service the mines. The change from rail to truck haulage, as the pits deepened, increased the need for additional shops. These shops are equipped for all types of maintenance and repair work, including complete overhaul of the large diesel truck engines. In addition, new equipment such as trucks and churn drills requires alterations and additions before being put into service. Designs are changed, guards and safety devices are added, and known wear points are reinforced. General shops operated a total of 8,518,822 man-hours during 1957, approximately 14 percent of the total man-hours for all mining operations in the entire district.

INJURY EXPERIENCE, LAKE SUPERIOR DISTRICT MINES AND PLANTS

The disabling-injury experience of all Lake Superior district mines and plants for the 12-year period 1946-57 is tabulated in table 1. Table 2 shows the experience at the open pit mines and table 3 the experience at beneficiation plants and general shops for the same 12-year period.

TABLE 1. - Operating companies, man-hours worked, and injury experience, Lake Superior district mines and plants, 1946-57

Year	No. of companies	Total hours worked	No. of lost-time injuries	No. of days lost or charged	No. of fatalities	Frequency rate	Severity rate	Fatality rate
1946	23	32,963,546	765	109,760	12	23.21	3,330	0.36
1947	21	43,039,615	951	188,797	24	22.10	4,387	.56
1948	24	48,258,544	891	190,920	19	18.46	3,956	.39
1949	26	44,074,032	852	136,674	16	19.33	3,101	.36
1950	24	48,214,117	784	133,341	15	16.26	2,766	.31
1951	24	61,974,377	921	154,838	15	14.86	2,498	.24
1952	23	57,226,778	824	212,779	28	14.40	3,718	.49
1953	28	64,571,876	929	127,598	12	14.39	1,976	.19
1954	26	50,529,229	673	127,283	14	13.32	2,519	.28
1955	26	52,256,326	817	97,373	9	15.63	1,863	.17
1956	26	54,938,212	917	146,320	16	16.69	2,663	.29
1957	26	60,746,795	944	172,437	20	15.54	2,839	.33
Average	25	51,566,121	856	149,843	17	16.60	2,906	.33

The injury-frequency, injury-severity, and fatality rates were computed by the American Standards Association Method of Recording and Measuring Work-Injury Experience, Z16.1, approved December 16, 1954, and indicate the number of disabling work injuries, total time charges in days, and number of fatalities per million man-hours exposure, respectively. Statistics for beneficiation plants were combined with those for general shops as a classification separate from open-pit mines.

The injury-frequency, injury-severity, and fatality rates for the two classifications are shown graphically in figures 1, 2, and 3 for the period 1946-57. Severity rates for the years preceding 1955 have been converted in the tables and graphs to conform to the new method of computation. Straight-line trends were calculated by the method of least squares.

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TABLE 2. - Operating companies, man-hours worked, and injury experience, open-pit mines, Lake Superior district, 1946-57

Year	No. of companies	Total hours worked	No. of lost-time injuries	No. of days lost or charged	No. of fatalities	Frequency rate	Severity rate	Fatality rate
1946	19	13,280,957	186	42,173	5	14.01	3,175	0.38
1947	18	17,801,587	195	36,533	4	10.95	2,052	.22
1948	20	18,203,834	169	38,265	1	9.28	2,102	.05
1949	20	17,472,767	203	37,828	4	11.62	2,165	.23
1950	21	19,241,959	182	42,743	5	9.46	2,221	.26
1951	18	22,731,618	201	36,990	3	8.84	1,627	.13
1952	17	21,441,428	164	36,469	4	7.65	1,701	.19
1953	21	24,718,732	226	36,457	3	9.14	1,475	.12
1954	19	17,805,743	133	29,914	3	7.47	1,680	.17
1955	20	18,530,460	157	35,567	4	8.47	1,919	.22
1956	18	19,573,458	137	25,214	2	7.00	1,288	.10
1957	18	19,461,778	110	46,940	6	5.65	2,412	.31
Average	19	19,188,693	172	37,091	4	8.96	1,933	.21

TABLE 3. - Operating companies, man-hours worked, and injury experience, beneficiation plants and general shops, Lake Superior district, 1946-57

Year	No. of companies		Total hours worked	No. of lost-time injuries	No. of days lost or charged	No. of fatalities	Frequency rate	Severity rate	Fatality rate
	Plants	Shops							
1946	6	6	4,024,460	28	1,659	0	6.96	412	0.00
1947	6	6	4,767,590	42	15,544	2	8.81	3,260	.42
1948	7	8	6,109,922	44	1,510	0	7.20	247	.00
1949	8	10	5,345,027	47	20,435	3	8.79	3,823	.56
1950	5	6	5,781,454	43	9,628	1	7.44	1,665	.17
1951	8	11	10,372,593	78	7,914	0	7.52	763	.00
1952	9	10	9,956,391	72	8,430	1	7.23	847	.10
1953	11	13	12,722,256	124	17,947	1	9.75	1,411	.08
1954	7	10	9,759,695	70	22,827	3	7.17	2,339	.31
1955	13	14	10,811,728	122	6,189	0	11.28	572	.00
1956	14	18	12,762,142	158	22,507	2	12.38	1,764	.16
1957	13	15	15,177,218	127	11,176	0	8.37	736	.00
Average	9	11	8,965,873	80	12,147	1	8.92	1,355	.11

The injury-frequency trend for open-pit mines, figure 1, shows a decrease of almost 50 percent over the 12-year period. The trend for beneficiation plants and general shops, however, shows an increase of slightly more than 40 percent during this same period. Identical improvements of approximately 34 percent in the severity trends over the 12-year period are shown in figure 2. The increasing trend of the frequency rates for beneficiation plants and general shops did not affect the fatality trend which shows an approximate 64 percent decrease, figure 3, during the period. The fatality trend for open-pit mines indicates a decrease of about 23 percent.

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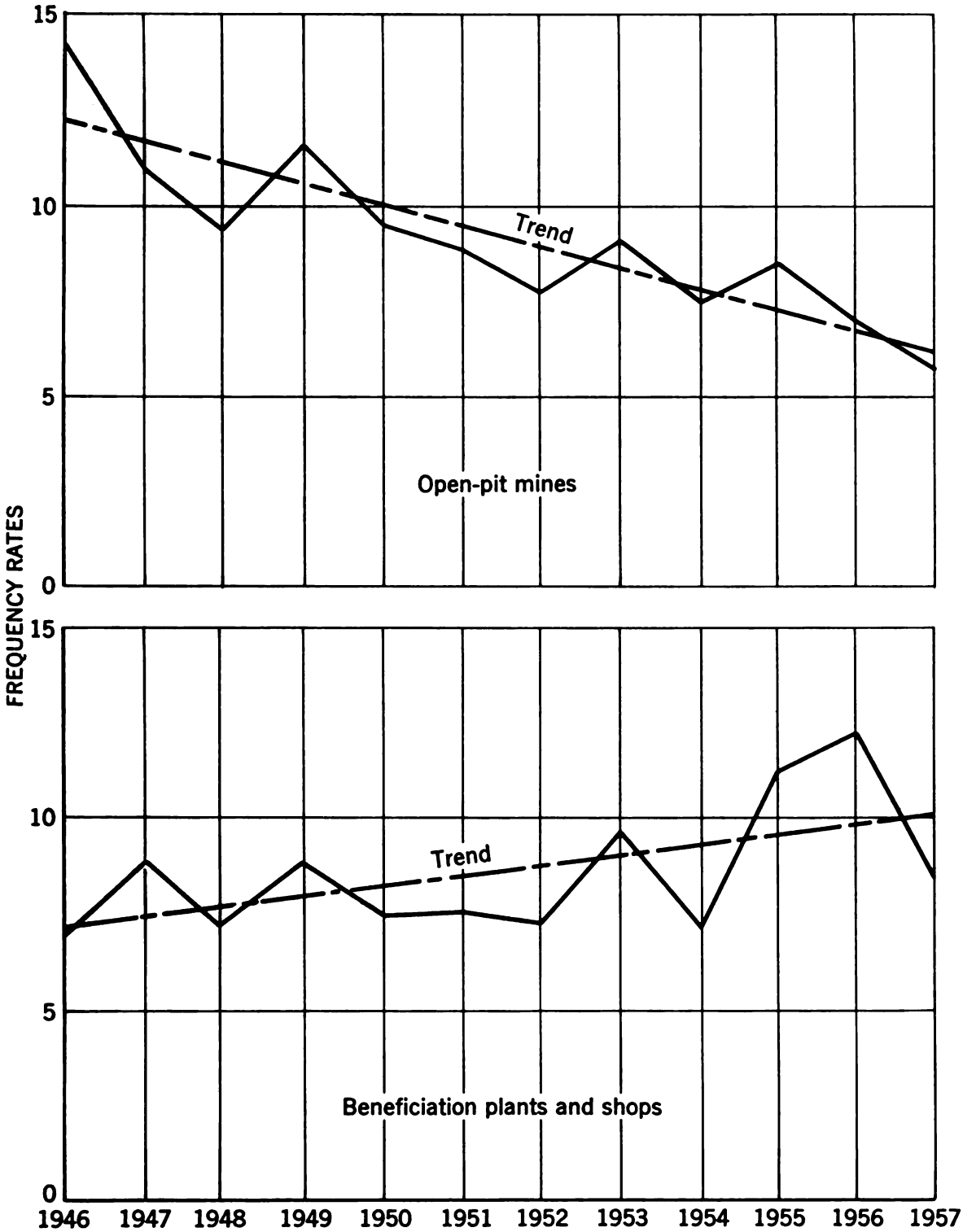

FIGURE 1. - Injury-Frequency Rates and Trends, Lake Superior District, 1946-57.

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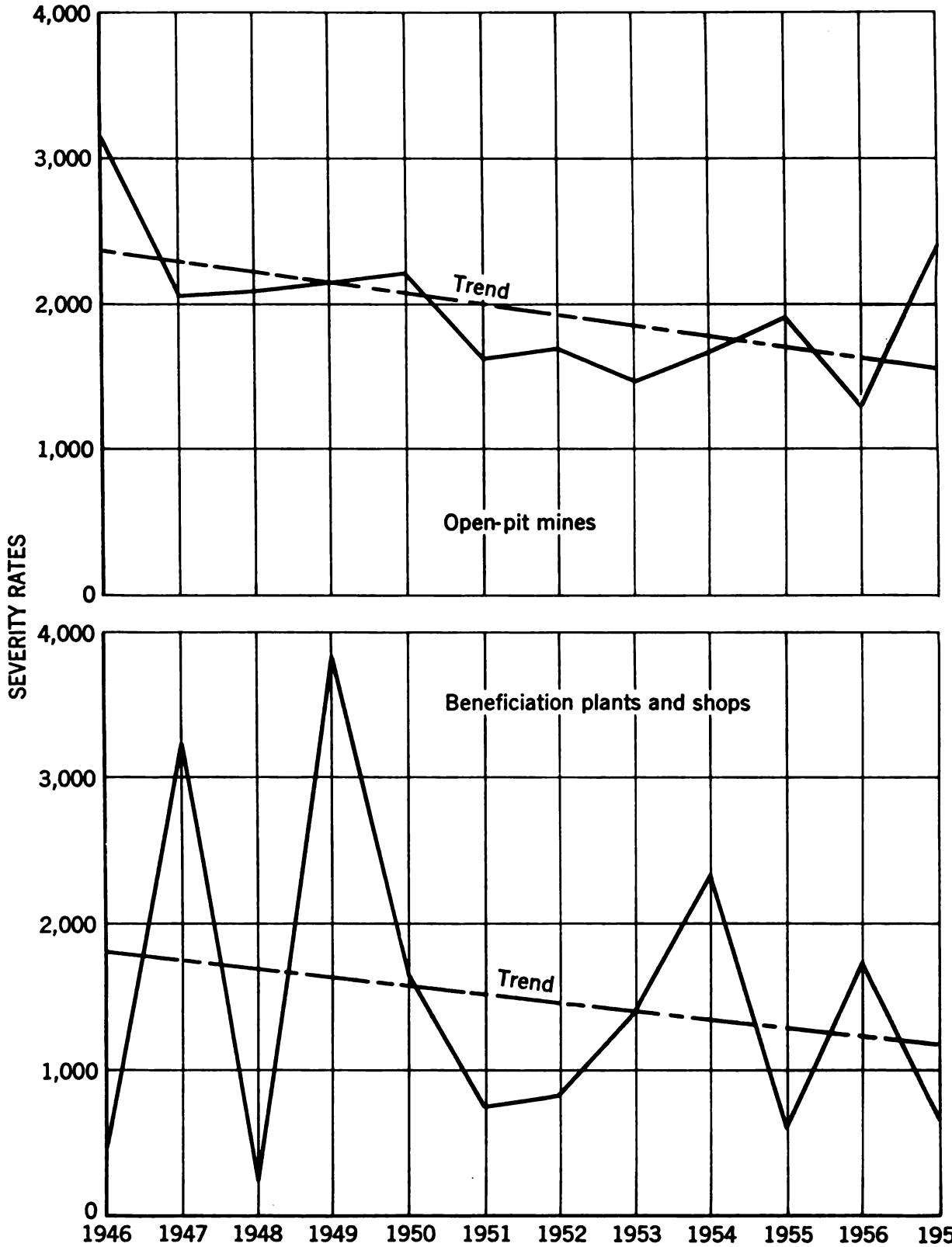

FIGURE 2. - Injury-Severity Rates and Trends, Lake Superior District, 1946-57.

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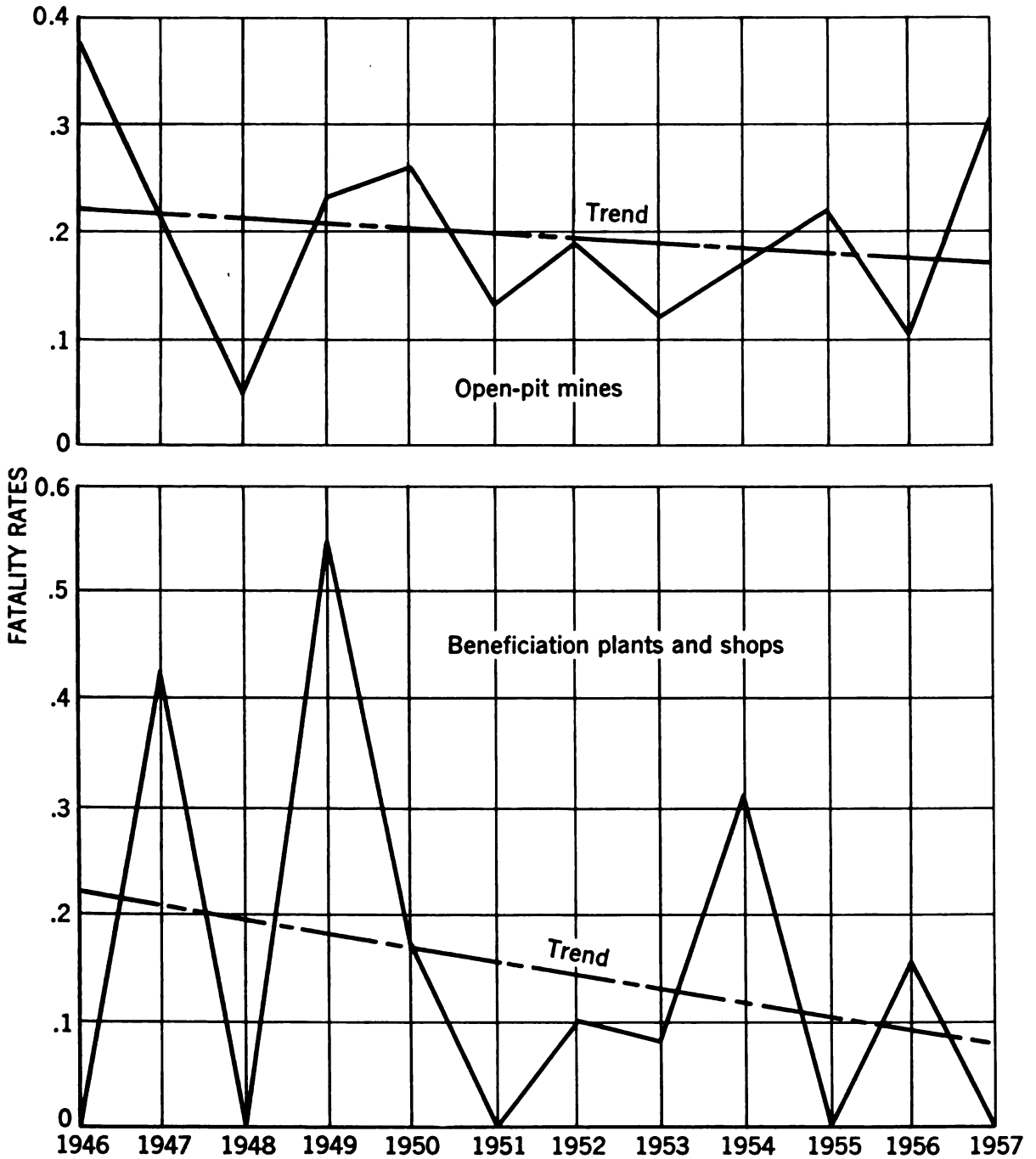

FIGURE 3. - Fatality Rates and Trends, Lake Superior District, 1946-57.

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CLASSIFICATION OF CAUSES OF INJURIES

A classification of the causes of injuries showing number of accidents, fatalities, number injured, total days lost, and days lost per injury, is tabulated in table 4. The figures in the column, total days lost, were obtained from the reports that listed this information. Because some of the reports did not include the days lost, the figures in the column, average number of days lost per injury, were computed by dividing the number of days lost for each category by the number of injuries in that category for which time lost was listed. Only 442 of the 494 accident reports studied listed the actual, charged or estimated time losses.

TABLE 4. - Classification of causes of injuries

Cause of injury	No. of accidents	No. injured	Percent of total injured	No. of fatalities	Percent of total fatalities	Days lost or charged	Percent of total days lost	Avg. no. of days lost per injury 1/
Falls of persons...	101	101	20.3	-	-	3,833	3.6	40.8
Handling materials.	99	100	20.1	-	-	4,604	4.3	51.2
Truck haulage.....	42	43	8.6	3	25.0	24,443	22.7	643.2
Drilling and drilling equipment	35	35	7.0	-	-	1,720	1.6	57.3
Moving machinery...	30	30	6.0	-	-	6,996	6.5	259.1
Hand tools	26	26	5.2	-	-	1,202	1.1	48.1
Falling objects....	24	25	5.0	-	-	1,281	1.2	55.7
Maintenance work...	24	24	4.8	-	-	1,182	1.1	51.4
Rail haulage.....	21	21	4.2	3	25.0	18,672	17.3	1,037.3
Shovels and cranes.	19	19	3.8	2	16.7	15,732	14.6	1,123.7
Tractors.....	11	12	2.4	1	8.3	6,447	6.0	716.3
Falling chunks.....	12	12	2.4	1	8.3	6,502	6.0	650.2
Flying objects.....	9	9	1.8	-	-	305	.3	43.6
Electrical.....	5	5	1.0	2	16.7	12,016	11.1	3,004.0
Explosives.....	5	5	1.0	-	-	322	.3	80.5
Miscellaneous.....	31	32	6.4	-	-	2,434	2.3	93.6
Total	494	499	100.0	12	100.0	107,691	100.0	243.6

1/ Only 442 of the 494 accident reports studied listed the time losses. The figures in the column, "Avg. no. of days lost per injury," were computed by dividing the days lost for each category by the number of injuries in that category for which time lost was listed.

Falls of persons and handling materials were the leading causes of injuries accounting for 20.3 and 20.1 percent respectively of the total injuries. Only 3.6 and 4.3 percent, respectively, of the total days lost were charged to these accidents. Truck haulage and drilling equipment ranked 3d and 4th in the causes of injuries.

The number of truck accidents involving trucks run over a pit bank or bench was surprising; 19 of the 42 truck accidents were of this type. Trucks were involved in three fatal accidents, but only one was caused by a truck going over the bank. Truck haulage ranked highest in the Total days lost column.

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Electrical injuries ranked highest in severity, with an average of more than 3,000 days lost per injury. Two of the five electrical accidents resulted in fatalities.

UNSAFE PRACTICES AND CONDITIONS

Considerable thought was given to the breakdown of unsafe practices and unsafe conditions. In general, unsafe practices were construed to mean acts that normally could be controlled and that deviated from accepted safe practices. Unsafe conditions in general were interpreted as conditions, created by either man or nature, that could have been corrected. The two classifications are not intended to place responsibility on either management or employees.

Several reports listed uneven or frozen ground and muddy working areas as unsafe conditions causing accidents. The writers felt that, in these examples, such factors are normal operating conditions during winter open-pit operations, and that the principal cause of the accident should have been listed as an unsafe practice, such as Failure to use ordinary caution." Accidents caused by unusual weather conditions were included under unsafe conditions.

In several cases where a report listed an unsafe practice as the only cause of an accident, the authors added a second cause as "inadequate supervision," if a supervisor was a member of the working crew or was present and did not correct the bad practice.

There were nine cases in which an unsafe personal factor had a direct bearing on the accident. The cases included one with an artificial leg, a second with an arthritic back, another with polio-atrophied arm and leg, and others with only one eye or very poor hearing. These were listed under unsafe conditions, because it was believed that these employees should have been placed in occupations where their disability would not be a handicap.

A breakdown of the accident causes showed that 374 accidents (75.7 percent of the total) resulted solely from unsafe practices and that 50 accidents (10.1 percent of the total) were caused by unsafe conditions. A combination of both unsafe practices and conditions caused 56 accidents (11.3 percent of the total), and 14 accidents (2.8 percent of the total) could not be classed under either unsafe practices or conditions because of insufficient information.

Table 5 lists the unsafe practices contributing to 430 accidents, 374 caused by unsafe practices and 56 by a combination of unsafe practices and unsafe conditions. In 88 cases, 2 or more unsafe practices contributed to the accident. "Failure to use ordinary caution" was the most common unsafe practice with 165 occurrences, followed by "Improper work procedures," with 156 occurrences. The 34 occasions listed for "Failure to wear protective clothing or equipment" are high, as virtually all companies have rules requiring the wearing of safety hats, hard-toed shoes, goggles, safety belts, and other safety equipment.

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TABLE 5. - List of unsafe practices contributing to 430 accidents

Unsafe practices	No. of occasions	Percent of total occasions	No. of fatalities	Percent of total (12) fatalities
1. Failure to use ordinary caution.	165	31.6	5	41.7
2. Improper work procedure	156	29.8	3	25.0
3. Unnecessary exposure to danger..	92	17.6	3	25.0
4. Failure to wear protective clothing or equipment	34	6.5	0	-
5. Lack of coordination between employees	25	4.8	1	8.3
6. Use of unsafe tools, improper tools, or improper use of hands	25	4.8	0	-
7. Failure to obtain help	11	2.1	0	-
8. Inadequate supervision	9	1.7	0	-
9. Other	6	1.1	0	-
Total	523	100.0	12	100.0

Table 6 lists the unsafe conditions contributing to 106 accidents, 50 caused by unsafe conditions and 56 caused by a combination of unsafe conditions and unsafe practices. There were two cases where two unsafe conditions contributed to the same accident.

"Faulty or unsafe equipment," was the principal unsafe condition disclosed by the study; 49 of 108 occasions noted were in this category. Faulty design of equipment contributed to several accidents, and a number of accidents resulted when known bad-order equipment was continued in operation. There were 23 occasions of an unsafe work area, 12 of which were unsafe bank conditions. "Inadequate guards or lack of guards" was listed 11 times, and "unsafe personal factors" was reported 9 times.

TABLE 6. - List of unsafe conditions contributing to 106 accidents

Unsafe conditions	No. of occasions	Percent of total occasions	No. of fatalities	Percent of total fatalities
1. Faulty or unsafe equipment	49	45.9	2	66.7
2. Unsafe bank	12	11.0	1	33.3
3. Inadequate guards or lack of guards	11	10.2	-	-
4. Unsafe work area (hazardous arrangement, congestion, etc.)...	11	10.2	-	-
5. Unsafe personal factors	9	8.3	-	-
6. Poor visibility	6	5.6	-	-
7. Insufficient clearance	4	3.7	-	-
8. Abnormal weather conditions	4	3.7	-	-
9. Other	2	1.9	-	-
Total	108	100.0	3	100.0

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TIME OF OCCURRENCE

The time of occurrence was listed in 428 of the 494 accident description reports. Figure 4 shows the hour of occurrence, with the approximate change of shifts indicated. Approximately 65 percent of the accidents (276 of the 428) occurred between 8 a.m. and 4 p.m.

Figures for the average number of men working on each shift were not available, and no attempt was made to calculate the frequency rates for the different shifts. However, it is interesting to note that there were four more accidents on the midnight shift than on the afternoon shift. The analysis of underground accidents[7/] showed about 85 percent more accidents on the afternoon shift.

The chart shows that the highest accident frequency for both day and afternoon shifts occurred during the second hour after the start of the shifts. Fewer accidents occurred during the hours when shifts were changing and at lunchtimes. More accidents were reported for the daylight hours of the afternoon shift than for the hours of darkness.

EXPERIENCE OF INJURED IN MINES, PLANTS, AND SHOPS

The total in-mines work experience of the injured employees is listed by job classification in table 7. This information was listed on 371 of the accident reports. Approximately 21 percent of the injured employees had less than 2 years experience compared to the 20 percent reported in the underground accident analysis.[8/] However, only 39.4 percent of the injured employees in open-pit operations, including beneficiation plants and shops, had more than 10 years total experience compared with 53.4 percent reported for underground mines.

EXPERIENCE OF INJURED ON THE JOB

On-the-job experience of the injured employees is classified in table 8. The classification shows that 104 of the 291 injured employees (35.7 percent) had less than 1 year of experience on the job they were performing when the accident occurred. In the analysis of underground accidents,[9/] 66 of 231 injured employees (28.6 percent) had less than 1 year of experience on the job they were performing when hurt. Because the tables do not indicate that a large percentage of the injuries occurred to new employees, job training may not be given adequate consideration at some mines and plants.

7/ Pynnonen, R. O., Stott, R. G., Stepan, J. B., Johnson, J. A., Analysis of 346 Accidents, Underground Iron-Ore Mines, Lake Superior District: Bureau of Mines Inf. Circ. 7744, 1956, 15 pp.

8/ Work cited in footnote 7.

9/ Work cited in footnote 7.

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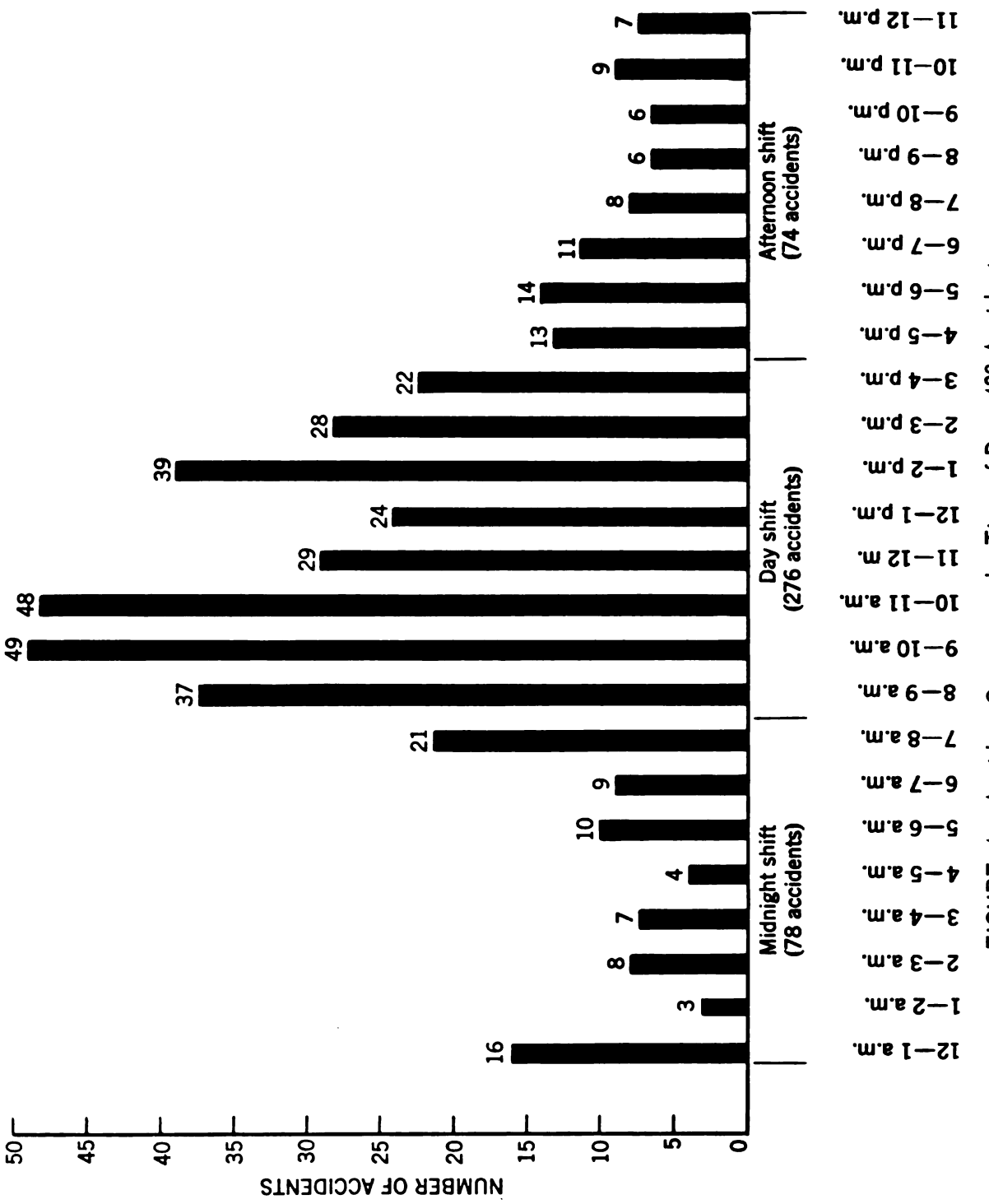

FIGURE 4. - Accident Occurrence by Time of Day, 428 Accidents.

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TABLE 7. - Total experience of injured in mines

Job classification	Less than 1 year	1 to 2 years	More than 2 but less than 5 years	More than 5 but less than 10 years	More than 10 but less than 20 years	More than 20 years	Total
Truck driver	5	3	11	9	7	3	38
Brakeman	0	2	3	4	5	4	18
Shovel operator, oiler	1	3	4	5	5	4	22
Supervisor	1	0	3	2	11	9	26
Tractor and grader operator.	0	4	1	1	4	2	12
Mechanic	1	2	13	23	15	10	64
Carpenter, machinist, blacksmith, welder, and electrician	2	3	4	14	9	10	42
Driller, blaster	8	4	7	10	10	8	47
Laborer, sampler, dumpman ..	15	11	8	9	9	5	57
Trackman	5	2	5	1	3	0	16
Miscellaneous	2	3	6	5	8	5	29
Total	40	37	65	83	86	60	371
Percent of total	10.8	10.0	17.5	22.3	23.2	16.2	100.0

TABLE 8. - Total experience of injured on the job

Job classification	Less than 1 year	1 to 2 years	More than 2 but less than 5 years	More than 5 but less than 10 years	More than 10 but less than 20 years	More than 20 years	Total
Truck driver	8	4	7	8	1	0	28
Brakeman	4	2	4	5	4	1	20
Shovel operator, oiler	3	0	5	2	1	1	12
Supervisor	3	3	8	6	1	1	22
Tractor and grader operator.	1	0	1	1	1	1	5
Mechanic	14	6	19	6	3	0	48
Carpenter, machinist, blacksmith, welder, and electrician	6	7	6	6	5	1	31
Driller, blaster	13	6	8	4	4	2	37
Sampler, laborer, dumpman ..	32	3	7	5	2	0	49
Trackman	10	2	3	0	1	0	16
Miscellaneous	10	1	8	1	1	2	23
Total	104	34	76	44	24	9	291
Percent of total	35.8	11.7	26.1	15.1	8.2	3.1	100.0

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